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REPORT

MRL-R-881

SENSITIZATION OF HIGH DENSITY SILVER AZIDE

TO STAB INITIATION

R.J. Spear, L.D. Redman and J.R. Bentley

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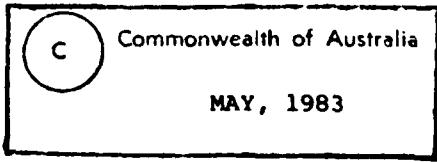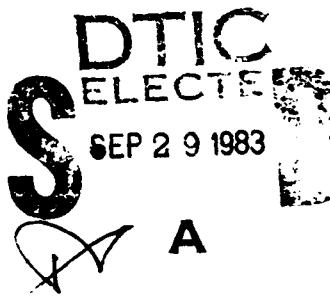
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The preparation of high density silver azide, bulk density 2.15 g/cm^3, in a free flowing crystalline form is described. Sensitivity data are given and the ability of both energetic and grit sensitizers to sensitize the material to stab initiation has been assessed. Some of the grit mixes are very susceptible to explosion during pressing. Experimental compositions based on "L" mix and N.O.L. 130, with LDNR or lead azide/styphnate replaced by silver azide and tetrazene by KHADNBF, were studied and show the potential of developing stab and percussion mixes based on silver azide.

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CONTENTS

SENSITIZATION OF HIGH DENSITY SILVER AZIDE TO

STAB INITIATION

1. INTRODUCTION

Primary explosive fillings in service stores are largely based on three materials: lead azide, lead styphnate and tetrazene. Lead azide, in its various forms, is the main primary explosive filling in detonators. Lead styphnate is employed either to produce an ignition, such as in priming compositions, or to provide high sensitivity to electrical initiation. Neither of these materials is sufficiently sensitive for most applications requiring mechanical initiation and 2-10% of tetrazene is incorporated as an energetic sensitizer to provide adequate sensitivity, eg., in percussion caps and stab detonators.

All three materials have well documented technical shortcomings. The most troublesome of the three is lead azide. Lead azide hydrolyses in the presence of moisture and carbon dioxide with loss of functioning ability, is incompatible with certain plastics used in modern fuzes and produces hazardous corrosion products with copper-containing alloys [1]. In addition, the modern trend towards miniaturisation has moved to the point where lead azide performs only marginally in miniature detonators [2]. Bluntly stated, the use of lead azide continues on such a vast scale only because no better materials have been developed.

Silver azide has been actively considered as a replacement for lead azide in detonators since it has superior chemical stability [2-4], higher detonation velocity [2] and performs satisfactorily in miniature detonators [2]. A major practical difficulty with silver azide has been the low bulk density obtained by the metathetical reaction [2,5,6], giving a material with poor flowing and handling properties. Despite this, and its higher cost relative to lead azide, it has been used in service [2]. A method for preparing material of high bulk density (> 1.5 g/cm^3) was discovered some ten years ago independently by one of us (J.R.B.) and Costain in the U.S. [2,7]. Details of our experimental procedure have not previously been published and are described here. U.K. workers have also described the preparation of

similar silver azide, but without experimental details [4,6]. A second major problem is the incompatibility of silver azide with tetrazene [3,5] and also antimony sulfide [3], the most commonly used grit sensitizer. The use of silver azide as a direct replacement for lead azide in stab and percussion sensitive compositions is therefore not possible without new sensitizers.

The purpose of the work described in this report was twofold. The major objective was to investigate the sensitization of high density silver azide to stab initiation and to provide preliminary assessment of the practicability of replacement of lead azide by silver azide in stab sensitive compositions. The synthesis and physical properties of high density silver azide, including data on sensitivity to initiation, are also detailed.

2. RESULTS AND DISCUSSION

2.1 Preparation of High Density Silver Azide

Preparation of silver azide by methods analogous to those used in production of the various types of lead azide gives a product of low bulk density. This results from the low solubility of silver azide in aqueous media, which leads to excessive nucleation and consequently very small crystals. The reagent normally used to increase solubility of silver azide in aqueous media is ammonia [2,4,6]; slow crystallisation can subsequently be achieved by evaporation of the ammonia. Crystals over 10 mm long can readily be grown this way [8,9].

The method used here, described in detail in the experimental section, involved initial reaction between silver nitrate and sodium azide in the presence of excess ammonia followed by slow ammonia evaporation in a series of temperature steps from 40-65°C. 1M $KHCO_3$ was present to control pH; this also affects crystal habit, producing more equant, less acicular crystals. The commercially available surfactant Empilan AQ100 was used to reduce crystal agglomeration during crystallisation. A photomicrograph of the product is shown in Fig. 1; in addition a few longer needles and needle clusters could be seen in the batch.

The method used by Costain [2,7] differs from ours in that higher temperatures over shorter periods were used for the evaporation, and neither $KHCO_3$ nor Empilan (or other detergent) was present. Instead, 3M acetic acid was used during the first evaporative stage to induce crystallisation and in the final stage to complete neutralisation and presumably to increase yield. The crystals obtained by Costain [2] were not as well defined as those obtained here, which correspond quite closely in size and shape to that designated as RD1374 [6]*. Note that our principal aim was to produce silver azide of high bulk density and the product we obtained had bulk density of 2.15 g/cm^3.

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* No detailed experimental procedure has as yet been published by the British for this crystal modification.

The product obtained by Costain had a density of 1.6 g/cm^3 [2], comparable with lead azide RD1343, 1.6 ± 0.05 g/cm^3 [10]. Costain presumably sacrificed bulk density for yield. We have not optimised our method for either crystal size distribution or total yield. The yield obtained here was acceptable (52.2%) and should be amenable to a substantial increase perhaps with some sacrifice of bulk density. Reaction time could also be considerably shortened.

2.2 Sensitivity of High Density Silver Azide to Initiation

The sensitivity of high density silver azide to initiation by mechanical, electrostatic and thermal stimulae was assessed; the results are detailed in Table 1. Results for lead azide RD1343 are listed for comparison. Ignition always resulted in propagation to detonation and no partials were observed.

Impact sensitivity was measured by the Ball and Disc Test which combines direct impact with friction by pinching. High density silver azide is comparable in sensitivity to lead azide RD1343 at the no fire level but the range to the all fire level is greater. Both materials ignite in the electric spark test at the lowest testing energies available (0.045 J) and a more accurate comparison would require a more sensitive test such as the Approaching Needle Test. Costain [2] quotes the electrostatic sensitivity of silver azide as 0.0094-0.018 J, compared with 0.0005 J for lead azide RD1333.

The behaviour of silver azide under heating is unusual for a primary explosive in that the ignition temperature is significantly higher than the melting point. The generally accepted values for the melting and ignition points are 251°C and 273°C respectively [11,12]. The values for our high density silver azide are significantly higher; 309°C and 400°C (T of I test) respectively. The melting point is almost identical to the 310°C reported recently for silver azide [9], where it was suggested that the previous values may have been obtained on impure silver azide. The ignition temperature, at 400°C, is very much higher than reported previously and significantly higher than lead azide RD1343 at 316°C (Table 1). A DSC trace showing both melting endotherm and ignition exotherm can be seen in Fig. 2.

2.3 Stab Sensitivity

Compacts of high density silver azide, pressed at 560 MPa, were subjected to stab action over a wide range of striker energies. Initiation consistently failed at the highest testing energy, ~ 1130 mJ, and out of a total 35 detonators tested only 3 fires were observed. Clearly, the striker energies at which a 50% fire level (Bruceton Analysis) [13] could be obtained are significantly above 1130 mJ. For comparison, the 50% fire level for lead azide RD 1343 pressed under identical conditions was previously found to be ~ 1000 mJ [14]. It should be noted that at these very high energies the needle penetrates the compacted silver azide so strongly that it remains

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wedged in, and the test probably is no longer relevant to pure stab action but combines percussion aspects as well.

2.3.1 Sensitization by Energetic Sensitizers

Silver azide and tetrazene are incompatible [3,5]; reaction occurs to give silver azidotetrazole which is hypersensitive, resulting in unpredictable spontaneous explosions of loose or pressed admixtures. The use of silver azide in stab and percussion sensitive mixes thus requires an alternative sensitizer to tetrazene. We have recently examined the sensitization of lead azide RD1343 to stab initiation by energetic sensitizers and have found a number of materials which have the potential to replace tetrazene in practical applications [14,15,16]. We have selected a number of the more promising materials, whose structures are shown below*, as potential energetic sensitizers on high density silver azide. The preparation of these sensitizers has been fully described previously [14,15,16] with the exception of KOxDNBF, whose preparation and explosive properties will be fully described in a forthcoming publication [17].

DDNP [14]   KAzDNP [14]   PNT [14,15]

X = NHOH   KHADNBF [16]
X = OH   KDNBF [14,16]   KOxDNBF [17]

LAT [14]

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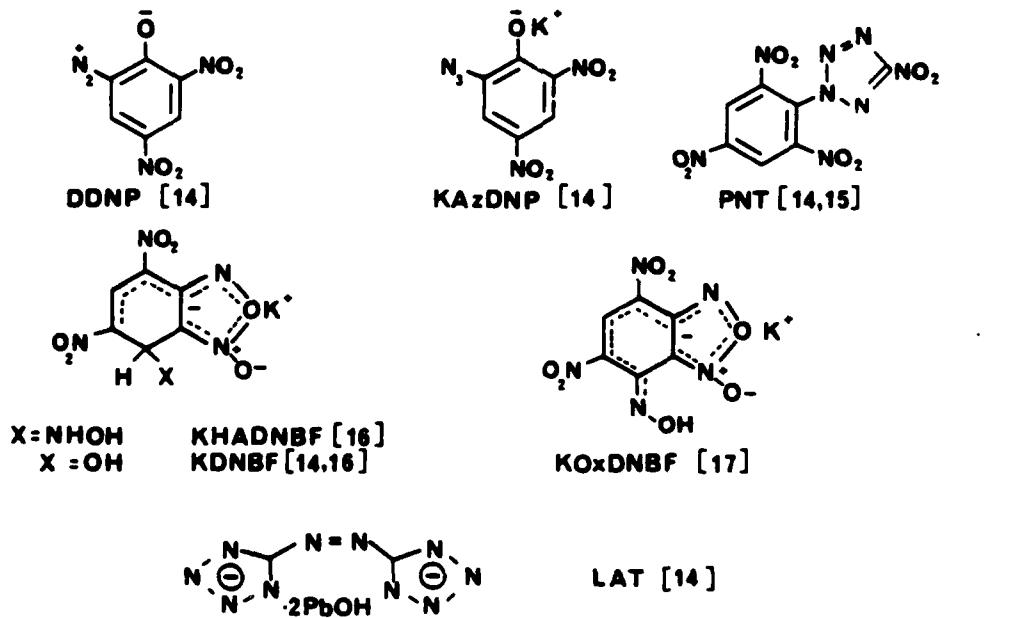
* Full names for the sensitizers are as follows:-

DDNP	6-Diazo-2,4-dinitrophenolate (diazodinitrophenol)
KAzDNP	Potassium 6-azido-2,4-dinitrophenolate
PNT	2-Picryl-5-nitrotetrazole
KHADNBF	Potasium 4-hydroxamino-5,7-dinitro-4,5-dihydrobenzofurazanide 3-oxide
KDNBF	Potassium 4-hydroxy-5,7-dinitro-4,5-dihydrobenzofurazanide 3-oxide
KOxKNBF	Potassium 4-hydroxamino-5,7-dinitrobenzofurazanide 3-oxide
LAT	DiLead 5,5'-azobis(tetrazolate) dihydroxide (lead azotetrazole)

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All the sensitizers mixed extremely well with the high density silver azide, even those that mixed poorly with lead azide [14], and the resultant compositions (10:1) showed little tendency to segregate. The compositions were pressed at 560 MPa and stab initiation energies were determined for the 50% fire level by Bruceton analysis [13]. The results, together with those for the corresponding lead azide RD1343 compositions [14,16,17], are listed in Table 2.

The most salient feature is that the stab initiation energies for the silver azide mixes are significantly higher than the corresponding lead azide mixes, and in many cases too high for consideration in practical use, where an upper limit of about 10-12 mJ is required. Are these higher energies for silver azide mixes a feature of silver azide, or do they result from the particular sensitizers chosen for this study? Tetrazene could not be used due to incompatibility, and it was therefore decided to measure the sensitization of silver azide by mercuric fulminate (MF), a material previously shown to substantially sensitize lead azide RD1343 to stab initiation [14]. Obviously MF could not be considered as a sensitizer for silver azide in practical application due to its poor stability. The result obtained was 16.3 mJ, substantially greater than for the corresponding mix with lead azide (Table 2). Thus it can be concluded that silver azide cannot be sensitized by energetic sensitizers to the same low levels of lead azide admixtures. Possible explanations are reserved for later in this section.

2.3.2 Sensitization by Grits

The sensitization of energetic materials by grit has been a very widely observed phenomenon [18,19]. Indeed grit is deliberately used to sensitize stab and percussion sensitive mixes as can be seen in the typical examples of such compositions listed in Table 3. VH2, a percussion primer, and "L" mix and N.O.L. 130 are compositions used in Australian ordnance while AN#6 is a widely used American composition [20,21]. Note that AN#6 contains no energetic sensitizer and relies solely for its sensitivity on grit sensitization. Antimony sulfide (Moh's hardness 2) and calcium silicide (Moh's hardness 3.5) are the most commonly used grits. These also serve as fuels for reaction with the oxidant present, usually barium nitrate (Table 3). Barium nitrate also provides some grit sensitization. In addition AN#6 contains 5% of the very hard grit carborundum (Moh's hardness 9.5) which presumably provides most of the sensitization.

Antimony sulfide and silver azide are incompatible [3] thus stab and percussion sensitive compositions based on silver azide using grit/fuels must employ grits other than antimony sulfide. We initially chose three grits for study of their sensitization of high density silver azide: calcium silicide, ground glass (Moh's hardness 4.5-6.5) and carborundum. These three were chosen because they are currently or have been in use in initiating compositions, and cover a wide range of hardness (3.5-9.5). Barium nitrate was also included as a typical oxidant with some grit properties. The grits were sieved through a 75 μm sieve with the exception of barium nitrate, where material passing through 106 μm but retained by 75 μm was used, to minimise agglomeration.

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Our initial experimental approach was to study compositions analogous with those of the energetic sensitizers, ie., 10:1 pressed at 560 MPa. However we encountered an almost immediate problem in that although the barium nitrate composition pressed well, the carborundum composition exploded at all attempted pressings and the calcium silicide compositions also had a high incidence of explosion during pressing. Voreck et al [21] have stated that "the carborundum in AN#6 causes a high rate of explosions during pressing operations because it grit-sensitizes the lead azide". Porter [22], in an extensive unpublished study of stab initiation, noted, at times, a high incidence of pressing explosions on lead azide, mercuric fulminate and lead styphnate compositions sensitized by addition of grits. Consideration of these two reports would suggest that is not surprising that problems were encountered during pressing operations.

Both increase in grit concentration [23,24] and pressing load [25,26,27] have been shown to markedly increase sensitivity. The relationship between stab sensitivity and pressing load has been reported for N.O.L. 130 [25], VH2 [26] and "L" mix [27]. In the latter two cases sensitivity increased sharply with increased pressing load till 160 MPa (VH2) and 200 MPa ("L" mix), then more gradually. We accordingly chose to modify our experimental conditions by pressing initially at 240 MPa, chosen to minimise differential effects of pressing load between compositions, and to study 20:1 admixtures. The grit action of aluminium oxide was also studied, this being a very hard material (Moh's hardness 9) of more rounded shape and possibly less prone to pressing problems.

20:1 admixtures of silver azide with calcium silicide, ground glass and carborundum were pressed at 240 MPa. The calcium silicide mixture had a low incidence of explosion during pressing (1/51) but the latter two, particularly ground glass (4/22), were quite sensitive to pressing. Attempts to re-press either the ground glass or carborundum compacts at 560 MPa resulted in 100% explosion and study was discontinued. The calcium silicide compacts re-pressed without incident at 560 MPa and 20:1 silver azide-aluminium oxide readily pressed at 240 MPa then re-pressed at 560 MPa. The effect of grit concentration was investigated for calcium silicide by 10:1 admixtures, which pressed without incident at 240 MPa but showed a high explosion rate either when compacts were re-pressed at 560 MPa (2/6) or when the composition was pressed at 560 MPa (2/13). Stab initiation energies were determined on the surviving compacts and these are detailed, together with incidences of explosion during pressing, in Table 4.

At 20:1 by weight and pressed at 240 MPa, calcium silicide (entry 2) sensitizes significantly better than either ground glass (entry 6) or carborundum (entry 9). The latter two results are particularly surprising since these were the compositions most sensitive to initiation while pressing. It can tentatively be concluded that pressing initiation occurred by physical action on the pressed compact and not by friction between the drift and mold or detonator tube - all explosions occurred when the press was fully down. Re-pressing of detonators pressed at 240 MPa from which any loose material had been brushed did not lower the explosion rate. Presumably a different initiation mechanism is operative for pressing and stab initiation and further work to try and elucidate this difference seems warranted.

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Calcium silicide (entry 3) performs significantly better than aluminium oxide (entry 8) at 20:1 by weight pressed at 560 MPa, despite the much greater hardness of the latter. Possibly the shape of the grit material is important in determining sensitization ability. Increase in sensitizer content was assessed on calcium silicide (entries 4,5). The 10:1 compact at 240 MPa is less sensitive than the 20:1 compact at 560 MPa, while the 10:1 mixture compacted at 560 MPa was quite sensitive to stab but also to pressing. Note that the stab initiation energy of this latter composition was higher than any of the energetic sensitizer mixes (Table 2) with the exception of KDNBF.

It is not unreasonable to assume that the main sensitivity of service mixes of the type detailed in Table 3 arises from the tetrazene (with the exception of AN#6 which contains no tetrazene) with secondary sensitization provided by the grit and fuel components - barium nitrate (Table 4, entry 1) moderately sensitizes the silver azide. The data in Table 4 also are consistent with pressing load being more important than grit content, both leading to increased sensitivity at higher levels.

2.3.3 Replacement of Lead Azide by Silver Azide in Stab Sensitive Mixes in Current Service Use

The replacement of lead azide by silver azide, and consequently tetrazene by a suitable energetic sensitizer, could lead to significant improvements in both hydrolytic and thermal stability of stab sensitive mixes and stab detonators. Of the stab mixes listed in Table 3 (VH2 is a percussion primer and doesn't contain azide), we chose to investigate such a replacement on two types:- an "L" mix type, containing 50% silver azide, 45% barium nitrate and 5% KHADNBF, chosen as the tetrazene replacement because it gave the best sensitization on silver azide (Table 2), and an N.O.L. 130 type consisting of 60% silver azide, 25% barium nitrate, 10% calcium silicide and 5% KHADNBF. Whereas the "L" mix type was a direct replacement, the N.O.L. 130 type replaced total lead styphnate/lead azide by silver azide, to minimise the number of components, while the barium nitrate was increased at the expense of calcium silicide (which replaced antimony sulfide) to minimise the possibility of explosions during pressing. An AN#6 type was not considered due to the problems of pressing silver azide-carborundum compositions.

The compositions mixed well and showed little tendency to separate upon standing. The "L" mix type was pressed directly at 560 MPa but because problems had been encountered in pressing the 10:1 silver azide-calcium silicide composition at 560 MPa, the N.O.L. 130 type composition was pressed initially at 240 MPa. No problems were encountered and a second batch was pressed directly at 560 MPa with 1/26 exploding during pressing. Possibly the barium nitrate acts to desensitize the silver azide-grit mix to pressing initiation. Stab initiation energies were determined and the results are listed in Table 5.

The low initiation energies observed for both mixes pressed at 560 MPa are clearly within the range for practical application. There is a marked increase in sensitivity in the N.O.L. 130 type composition as pressing load is increased, similar to that shown by the calcium silicide admixtures in

Table 4. Note that the aim here was not to produce an optimised composition but, as has been done, to demonstrate that such a composition is potentially feasible. Further refinement of sensitivity/performance characteristics should be achievable by variation in formulation and pressing load, eg., calcium silicide may not be the best grit/fuel to use with silver azide. An additional point of interest is that it would appear that N.O.L. 130 itself is not optimally designed with respect to the explosive constituents [21] hence this should be an area of future research interest.

2.3.4 A Proposed Explanation for the Lower Stab Sensitivity of Silver Azide and Admixtures Relative to Lead Azide and Admixtures to Stab Initiation

It is generally agreed the stab initiation of explosive compacts is thermal in origin [14,23,28]. Hot spots, formed by frictional processes (needle on explosive crystals, friction between neighbouring crystals), lead to ignition and subsequently explosion or detonation [14,28]. A number of material properties have been identified as important for sensitivity to stab initiation. For sensitized mixtures, the ignition temperature (T of I) of the sensitizer seems the dominant factor with low stab initiation energies being associated with low sensitizer T of I [14]. Important factors for initiation of single component compacts are friction coefficient, specific heat, thermal conductivity and density of the explosive material [28].

The high T of I of silver azide, 400°C, would not normally be associated with a high degree of stab sensitivity. Indeed the lesser sensitivity of silver azide relative to lead azide (Table 3) probably results primarily from its higher ignition temperature - although lead azide is harder than silver azide [29], this would be somewhat offset by its lower friction coefficient [29].

The higher T of I again probably explains the difference in sensitivity between the silver azide and lead azide sensitized mixtures (Table 2). High speed photography on "L" Mix during stab penetration has shown that a number of initiation sites occur, both at and away from the needle (cf. friction mechanism above) [30]. Some or all of these sites may not be of sufficient energy to ignite the main component when it is silver azide but would with lead azide with its lower T of I. Another factor which must also be considered is the melting of silver azide well below the ignition temperature - this may have the effect of quenching some sites where ignition of the sensitizer had occurred, ie, ignition occurs but propagation fails. Indeed Bowden and Yoffe [31] have commented that " The behaviour of compounds such as silver azide which have melting points below the ignition temperature is different from those which explode without melting," where burning rather than detonation (as for lead azide) can result. Presumably this may lead to a greater tendency to propagation failure.

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3.   CONCLUSION

Silver Azide is relatively insensitive to stab initiation but can be sensitized to a high degree by suitable energetic sensitizers. Grit sensitizers also sensitize to a lesser degree but the mixes show tendency for explosion to occur during pressing. Stab initiation energies sufficiently low for practical use can be obtained for compositions based on those in current service use ("L" mix, N.O.L. 130) and certainly indicate that replacement of lead azide by silver azide in stab detonators is feasible. The sensitizer KHADNBF must be considered to be a strong contender as a replacement for tetrazene and further studies on this material, particular stability/compatibility, seem warranted.

4.   EXPERIMENTAL

4.1   High Density Silver Azide

The preparation was carried out on a semi-technical scale using a 10 L pan with remote handling. An aqueous silver nitrate solution (1M, 500 mL) was placed into the pan, diluted with water (2L) then 10% aqueous Empilan (100 mL) was added. With stirring, aqueous ammonia (8M, 360 mL) and 1M aqueous potassium bicarbonate (1 L) were then added and the entire solution was heated to 40°C. While continuing the heating and stirring, an aqueous solution of sodium azide (1M, 500 mL) was added remotely over about 30 s. After 2 h the tempeature was raised to 50°C and after a further 2 h, during which very little crystallisation had occurred, the temperature was raised to 60°C. Crystallisation commenced at this stage and after 0.5 h the temperature was raised to 65°C, held there 0.5 h then cooled. The product was recovered and dried in air. Yield 46 g (52.2%).

4.2   Bulk Density Determination

Bulk density was determined by accurately weighing 2.0014 g of the above silver azide into a bulk density tube then addition of n-butanol as liquid phase. Measurement was made after 0.5 h. A second measurement taken 0.5 h later was unchanged. The value obtained was 2.15 g/cm^3.

4.3   Sensitivity Measurements

Sensitivity to impact was measured using a Ball and Disc apparatus constructed in these laboratories to ERDE specifications. All ignitions resulted in detonation.

Sensitivity to electrostatic initiation was assesed on an instrument built in these laboratories to ERDE specifications for the Electric Spark Test. Ignition to detonation occurred at the lowest testing energy, 0.045 J, and higher energies were accordingly not tested.

Thermal behaviour was initially studied at a heating rate of 10°C/min using a Leitz Ortholux microscope with an attached Mettler FP-2 hot stage, and subsequently by differential scanning calorimetry (DSC) using a Perkin Elmer DSC-2B. Experimental conditions were vented aluminium pans under a flowing nitrogen atmosphere (15 mL/min), heating rate 40°C/min. Ignition temperatures were determined on an instrument built to specifications for the ERDE T of I test. Samples of 50 mg were heated at 5°C/min and measurements were performed in triplicate.

4.4 Energetic Sensitizers

The preparation of DDNP [14], KAzDNP [14], PNT [14,15], KHADNBF [16], KDNBF [14], LAT [14] and MF [14] have previously been described in detail. The preparation of KOxDNBF will be described in full in a forthcoming publication [17]. All materials were sieved before mixing through a 300 µm sieve to ensure reasonable homogeneity of particle size and to break up crystal aggregates.

4.5 Grit Sensitizers

Calcium silicide, carborundum, and aluminium oxide were commercial materials which were used as obtained, barium nitrate was ground prior to use. Ground glass was prepared by crushing and grinding soda glass. All materials were sieved through 106 µm and 75 µm sieves and only material passing through the 75 µm sieve was used except for barium nitrate where material retained by the 75 µm sieve was used.

4.6 Preparation of Sensitized Mixtures

Explosive compositions were prepared by adding the sensitizer(s) to the silver azide in the appropriate weighed amounts to achieve a batch size of 1.2-1.5 g, eg. silver azide (1.25), DDNP (0.125 g) for the 10:1 composition. Mixing was achieved by fold mixing on a sheet of paper and appeared to be excellent for all sensitizers.

4.7 Preparation of Experimental Detonators

Experimental detonators were prepared in mild steel tubes, 6 mm o.d., 3.2 mm i.d., length 6 mm, prepared from commercially available tubing. A back filling of lead monoxide was first pressed into the tube using a remotely controlled Pongrass press at a pressure of 560 MPa. The overall column length of lead monoxide was about 4 mm, requiring a mass of about 300 mg; variations resulted from small variation in diameter of the tubes. The experimental composition (45-50 mg) was then added on top and the unit repressed at 560 MPa or 240 MPa (see text for specific examples).

4.8 Determination of Stab Initiation Energies

The experimental set up, consisting of a drop tower test rig fitted with a quick release mechanism, has previously been described in detail [32]. Four strikers were used: 14.5 g for energies up to 55 mJ, 55.2 g for energies up to 300 mJ and 135 g and 228 g for the least sensitive compositions. The striker body was refitted with a new needle after every test whether or not a fire occurred. The needle was silver steel hardened to 650 HV with a 0.08-0.20 mm flat on the tip. In each experiment the striker was released from a pre-set height to impact on the experimental detonator supported in an aluminium holder held in a mild steel base. Each testing was assessed as fire or no fire by sound (very loud for a positive fire) and visual inspection of the detonator tubes. A no fire resulted only in an obvious identation into the compacted explosive. The detonators were not retested after a no fire and were destroyed chemically.

Preliminary determinations were conducted at a number of heights to obtain an approximate 50% fire level. The needle height was then varied using regular intervals of approximately 10% of this level. With the exception of the three compositions noted in Table 4, 25 detonators were tested for each experimental composition. Results were analysed by the Bruceton method [13] and represent the 50% fire level. Standard deviations have not been included; the Bruceton method of analysis is designed to given an overall estimate of the population from a limited number of samples. Statistical interpretation of the results derived from sample sizes used here give a reliable estimate of 50% functioning levels but not for standard deviations.

5. ACKNOWLEDGEMENTS

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TABLE 1. Sensitivity Data for High Density Silver Azide
and Lead Azide RD 1343.

	Observation			
Test	Silver Azide		Lead Azide	
Ball and Disc[a]	16 cm	10/10		
	15 cm	6/10		
	14 cm	6/10		
	13 cm	6/10	13 cm	10/10
	12 cm	4/10	12 cm	8/10
	11 cm	2/10	11 cm	5/10
	10 cm	2/10	10 cm	4/10
	9 cm	2/10	9 cm	1/10
	8 cm	0/10	8 cm	0/10
Electric Spark[a]	Fires 0.045 J		Fires 0.045 J	
T of I[a]	400, 400, 400°C		315, 316, 316°C	
DSC (40°C/min)	Endotherm (melting) 309°C			
	Exotherm onset 335°C		Exotherm onset 310°C	
	max. 395°C		max. 346.5°C	

a   Ignition results in detonation

TABLE 2. Stab Initiation Energies for 10:1 Admixtures of
High Density Silver Azide with Energetic Sensitizers

Sensitizer	Ignition Temp (T of I, °C)	Stab Initiation Energy, 50% Level[a] (mJ)	
		Silver Azide (10:1)	Lead Azide (10:1)[b]
DDNP	160	13.1	5.2
KAzDNP	133	19.3	6.5
PNT	156	24.9	11.1
KHADNBF	136	11.2	6.5
KDNBF	200	37.1	15.4
KOxDNBF	153	16.4	7.1
LAT	230	19.1	15.4
MF	158	16.3	6.1
Tetrazene	136	Incompatible	3.3
PURE SILVER AZIDE	400	>1100	
PURE LEAD AZIDE RD1343	316		~1000

a   Obtained by Bruceton Analysis [13].

b   For comparison, data from Refs [14-17].

TABLE 3. Some Typical Percussion and Stab Sensitive Mixes in
Current Service Use.

	VH2 (TYPE) %	"L" MIX %	N.O.L. 130 %	AN#6 %
LEAD AZIDE			20	28.3
LEAD STYPHNATE	38		40	
LEAD DINITRORESORCINATE		50		
TETRAZENE	2	5	5	
BARIUM NITRATE	39	45	20	
LEAD PEROXIDE	5			
POTASSIUM CHLORATE				33.4
CALCIUM SILICIDE	11			
ANTIMONY SULPHIDE	5		15	33.3
CARBORUNDUM				5

TABLE 4. Stab Initiation Energies for Admixtures of High
Density Silver Azide and Grits.

Entry	Grit	Silver Azide :Grit Ratio	Pressing Load(MPa)	Stab Initiation Energy (mJ)[a]	Explosions in Pressing
1	Barium Nitrate	10:1	560	~290	0/25
2	Calcium Silicide	20:1	240	165	1/51
3	Calcium Silicide	20:1	560	103	0/25[b]
4	Calcium Silicide	10:1	240	119	0/31
5	Calcium Silicide	10:1	560	34[c]	2/13, 2/6[b]
6	Ground Glass	20:1	240	>500[d]	4/22
7	Ground Glass	20:1	560		1/1[b]
8	Aluminium Oxide	20:1	560	190	0/25[b]
9	Carborundum	20:1	240	390[e]	2/22
10	Carborundum	20:1	560		1/1
11	Carborundum	10:1	560		2/2

a   50% level obtained by Bruceton Analysis [13].

b   Pressed first at 240 MPa then repressed at 560 MPa.

c   Only 15 tested.

d   Only 6 tested, no fires obtained.

e   Only 20 tested.

TABLE 5. Stab Initiation Energies for Experimental Stab Sensitive Mixes Based on "L" mix and N.O.L. 130.

		"L" mix type	N.O.L. 130 type
	Silver Azide	50%	60%
	KHADNBF	5%	5%
Composition	Barium Nitrate	45%	25%
	Calcium Silicide		10%
Stab Initiation	Pressed at 560 MPa	6.0 mJ	5.7 mJ[a]
Energies	Pressed at 240 MPa		18.7 mJ

a   1/26 exploded during pressing.
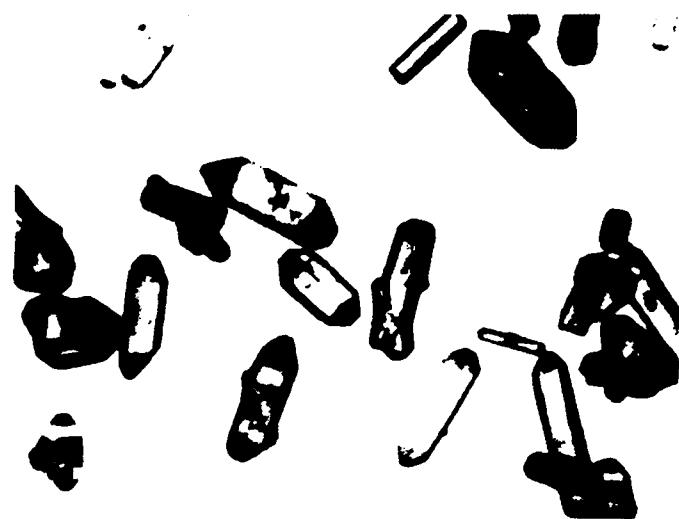
Fig. 1   Photomicrograph of High Density Silver Azide (X140)
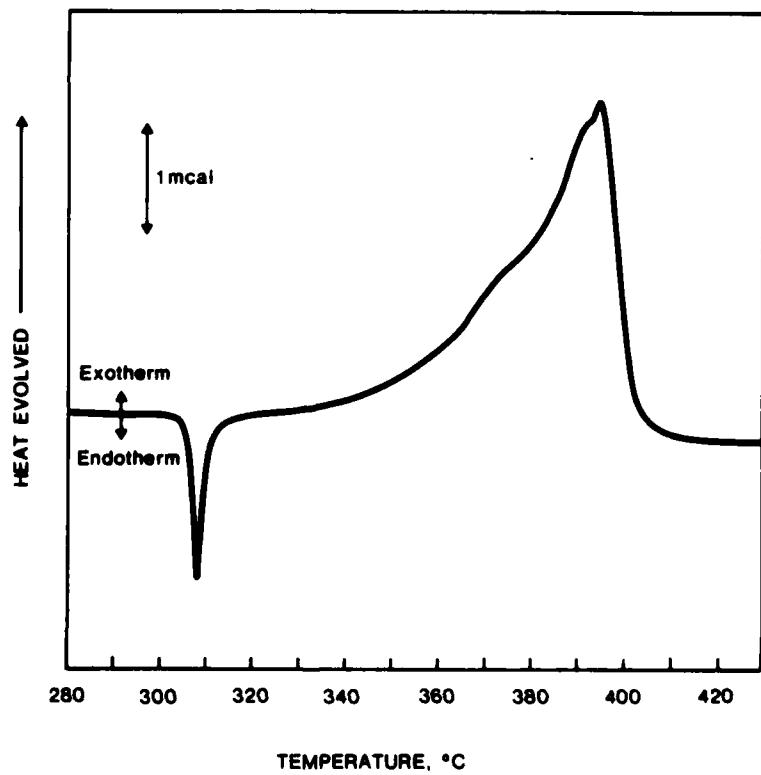

Fig. 2   DSC Thermogram for Silver Azide, heating rate 40°C/min, 0.35 mg.

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